FORM NO. 51-4C
MAR 1952

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CENTRAL INTELLIGENCE AGENCY
INFORMATION FROM
FOREIGN DOCUMENTS OR RADIO BROADCASTS

REPORT
CD NO. [redacted]

COUNTRY	USSR	DATE OF INFORMATION	1952, 1953
SUBJECT	Economic; Technological - Machine tools, mineral-ceramic cutting tools		
HOW PUBLISHED	Monthly periodicals	DATE DIST.	4 Jan 1954
WHERE PUBLISHED	Moscow	NO. OF PAGES	10
DATE PUBLISHED	Apr 1952 - Jul 1953		
LANGUAGE	Russian	SUPPLEMENT TO REPORT NO.	

THIS IS UNEVALUATED INFORMATION

SOURCE As indicated

MINERAL-CERAMIC CUTTING TOOLS

/The following report contains information from various Soviet periodicals on the development and application of mineral-ceramic cutting tools. [redacted]

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Numbers in parentheses refer to appended sources./

Thermocorundum

The cooperative work of Soviet specialists in metallurgy, ceramics, metal cutting, and cutting-tool design has led to the development of high-production and inexpensive mineral-ceramic tool materials. One of these materials is thermocorundum, which does not contain tungsten, titanium, or cobalt.

Research work at VNII (All-Union Scientific Research Tool Institute) and practical application at a number of plants have shown great potentials for using thermocorundum tools in machining light and nonferrous metals, and in finish and semifinish machining of steel, cast iron and various minerals.

The following table gives the physical and mechanical properties of various tool materials including thermocorundum (Variant 14) produced by VNIASh (All-Union Scientific Research Institute of Abrasives and Grinding):

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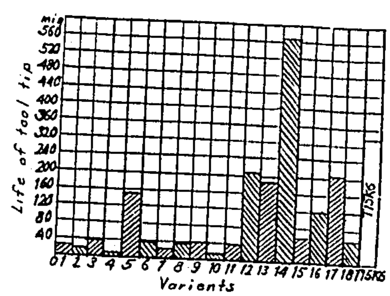
Type of Tool Material	Tool Material	Physical Properties: Heat Conductivity cal/cm.sec.° C	Physical Properties: Specific Density [g/cc]	Mechanical Properties: Rockwell Hardness (scale A)	Mechanical Properties: Bending Strength (kg/sq mm)	Mechanical Properties: Compressive Strength (kg/sq mm)
Hardened carbon steel	EU12	--	--	--	360	400
Hardened high-speed steel	R18	0.05	8.73	83	370	380
Tungsten-carbide hard alloy	VK8	0.14	14.45	88.5	140	330
Tungsten-carbide-cobalt hard alloy	T15K6	0.065	11.01	90.2	115	400
Mineral-ceramic material thermocorundum produced by VNIASh	Variant 14	Corundum 0.0055 at 200°	3.75	86-92	~30	90-150
Structural carbon steel	45	0.1-3	7.8	--	~140	--

It has been established through experimentation that the homogeneity and porosity of thermocorundum tips determine to a large degree their cutting properties. A darkening of the tip after it is rubbed with graphite and a small amount of kerosene indicates great porosity and decreased strength. A tip that darkens after this test should not be used. Only white thermocorundum tips which show no signs of cracks after being magnified 20 times are suitable.

The VNII has done a great deal of work on determining the cutting properties of various kinds of thermocorundum tips. The following graph gives the tool life of 18 variants of thermocorundum. The life of hard-alloy T15K6 is also given for comparison:



Graph of arithmetical mean of life of thermocorundum tips: Wear of tip, 0.8 millimeters; cutting speed, 120 meters per minute; feed, 0.17 millimeters per revolution; depth of cut, 0.5 millimeters. Material machined: Steel 45, hardness H_B 179-197.

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Experiments at VNII have established that the life of cutting tools with thermocorundum tips in machining steel 45 (ultimate strength: 65 kilograms per square millimeter) is equal to the life of cutting tools with T15K6 hard-alloy tips, and in machining cast iron of H_B 179-197 hardness, it is equal to the life of VK8 hard-alloy-tipped tools.(1)

Data from various plants on the life of thermocorundum cutting tools are given in Table 1:

Table 1

Name of Part	Material	Cutting Speed (m/min)	Feed (mm/rev)	Depth of Cut (mm)	Tool Life (min)
Fluted cylinders, shafts, worm gears	Steel	106-145	0.4-0.76	0.75-2.0	18
Lifting blocks, gears, bushings (in machining skin)	SCh 12-28	202	0.15	2.5	12.4
Shafts and axles	Steel 35	120-180	0.2	4	60
Shafts and axles	Steel 45	76-140	0.25	3-4	45
Shafts and axles	Steel 45	165	0.3	5	65
Unions	Steel 45	80-120	0.25	2.5	60
Disks	Steel 3	320	0.25	3	45
Gears	Steel 45	180	0.3	3	70
Various parts	Steel 20	145	0.1	2.5	60
	Cast iron	210	0.1	3	45
	Steel 35 (undercutting face 500 mm in diameter)	420	0.2	1	50
	Stainless steel				
	EZh2	175	0.25	4	30
	Steel 45	678	0.15	2.0	55
	KhVG	350	0.22	2.5	30
	Steel U10A	315	0.30	2.0	45
	Steel 30	263	0.40	3.0	90

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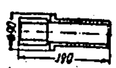
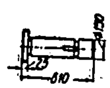
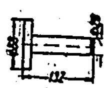
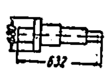
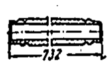
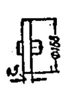
Table 2 gives data compiled by B. M. Ganfel'd on cutting conditions used in machining parts with thermocorundum tools. The average tool life in machining under these conditions is 20-75 minutes.

Table 2

Sketch of Parts	Material	Machine Tool	Cutting Conditions: RPM	Speed (m/min)	Feed (mm/rev)	Depth of Cut (mm)
	Steel 3	1A62	1200	150	0.24	1.5
	(OtsS 6-6-3) Sch 15-32	1A62	1200	640	0.30	1.5
	SCh 15-32	DIP 300	480	135	0.32	5.0
	Steel 45	1A62	950	537	0.20	1.5
	Steel 45	1A62	1200	278	0.35	2.0
	SCh 15-32	DIP 300	480	226	0.32	1.5
	SCh 35	1A62	1200	256	0.40	4.0
	SCh 45	1A62	1200	301	0.30	2.0
	SCh 45	1A62	1200	245	0.30	2.0
	SCh 15-32	1A62	1200	630	0.24	1.5

*Tips, Model 02 No 0225 0231, GOST 2209-49, are now being manufactured in series production.(2)

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Microlite

Basically, microlite [another type of mineral-ceramic metal-cutting material] is composed of aluminum oxide. Natural aluminum oxide known as corundum, is exceptional for its high degree of hardness and high melting point. However, artificial aluminum oxide, obtained chemically from bauxite, is used in the production of corundum items.

In developing microlite as a cutting material, various corundum materials were studied with optical and electronic microscopes. It was found that the microstructure of microlite differed a great deal from that of other corundum materials such as thermocorundum, "zinterkorundum" [sintered corundum?], etc. In microlite, the crystals are very compact, the intercrystalline layer is very thin, and the crystals themselves break down easily. The average size of a microlite crystal does not exceed 3 microns. Other corundum materials are made up of comparatively large crystals (15-100 microns and even larger) which are not closely packed and have a notably thick intercrystalline layer.

In testing microlite cutting tools at the TsNIITMASh (Central Scientific Research Institute of Technology and Machine Building) at a cutting speed of 150 meters per minute, one of the tools lasted for 43 hours, while the average life of the tools in this group was 26 hours. The life of a T15K6 hard-alloy cutting tool is only 3-5 hours.

Because of the brittleness of microlite, the cutting tools must be ground at low speeds and all impacts must be avoided. Microlite cutting tools must be ground with carborundum abrasive wheels at a speed of 1.5-3 meters per second and with continuous wetting with an aqueous solution of soda. This solution reduces the hardness and speeds the grinding process.

The grain size of the wheel must not exceed 60-80; even a finer grain, which would produce a better quality of cutting edge at slightly lower grinding speeds, would be preferable. Grinding in stages is recommended where rough grinding is to be done with a wheel of 40-60 grain size, or fine grinding with a wheel of 80-100 grain size. During grinding it is absolutely necessary that the wheel rotation be directed toward the cutting edge of the blade; otherwise, its cutting edge may be chipped.

It must be emphasized that microlite cutting tools must be lapped. Only in extreme cases can this lapping be replaced by grinding with a fine abrasive wheel (100-120 grain size). Microlite tools can be lapped with any lapping paste or abrasive powder of 200-320 grain size.

When microlite came into use for metal-cutting tools, the problem of fastening it to the tool shank arose. It was found that the new material would not adhere satisfactorily to metal with ordinary metal solders (brass, copper, etc.). Microlite will, however, combine with a metal or alloy if it is metalized.

In the metalization process a finely powdered metal such as iron, nickel, silver, or cobalt is mixed with an adhesive compound such as solutions of shellac or rosin and applied with a brush or sprayed on the surface of the specimen. The dried specimen undergoes heat treatment in a neutral atmosphere at a temperature of 1,400-1,550 degrees [centigrade] for iron metalization and 650-800 degrees for silver. The ceramic specimen can then be soldered to metal by the ordinary method.

Another method of fastening microlite tips on tool shanks is by an assortment of special binders. These binders can be organic or inorganic compounds. Among the organic binders is the well-known adhesive, carbinol BF-2. A layer of this adhesive is applied for fastening the parts, after which heat treatment at 120-150 degrees takes place. Organic binders join the microlite and metal firmly, but the heat resistance of such a joint does not exceed 70-80 degrees.

Among inorganic binders that can be used are various silicate cements. Fastening with silicate cements is possible with or without heating.

Soldering microlite with glass cement (steklotsement) does not differ in principle from ordinary soldering with copper or brass solders. A powder of glass cement is applied to the recess in the holder where the microlite tips are fitted and heated to 850-900 degrees. The glass cement melts in 5-10 minutes and a compact and sufficiently strong joining of the metal and microlite takes place.

The new tool material has already found application in other branches of industry. For example, microlite is used successfully for dies in the hot pressing of metals. In instrument building, it is used instead of the ruby.

Since 1951, microlite as a metal-cutting material has been known in industry as TsM-332.(3)

New mineral-ceramic cutting tools have been tested on a number of finishing operations in turning bearing rings at the Moscow First State Bearing Plant. The tests show that they are completely satisfactory for these operations.

Mineral-ceramic TsM-332 tips, model 0225, produced by the Moscow Hard Alloys Combine, were used in the tests. The mechanical properties of this material are as follows: [Rockwell] hardness (Scale A), 86-92; bending strength, 30 kilograms per square millimeter; compressive strength, 90-150 kilograms per square millimeter.

Boring and form tools were manufactured by fastening the ceramic tip with BF-4 adhesive, with a solder made of MKhTI (Moscow Institute of Chemical Technology imeni Mendeleyev) glass cement, or by mechanical fastening. Before fastening, the recess of the tool shank was washed with acetone and dried.

In using adhesive BF-4, the surfaces of the tip and the recess of the tool were equally covered with a thin layer of this adhesive and dried for 10-15 minutes at room temperature. The adhesive was again applied to each item and the two parts were clamped together. The cutting tool was then placed in an electric furnace with a temperature of 160 degrees for 30 minutes.

In using the glass cement solder, the tool shank with its tip was heated in an electric furnace to 800 degrees, which is the melting point of glass cement. After the glass cement had melted, the tool was removed from the furnace and placed on an asbestos mat to cool. When it had cooled, the overflow of glass cement was cleaned off its surface.

The mineral-ceramic cutting tools were ground with wheels made of green silicon carbide, 60 grain size, SM2 hardness, at a wheel speed of 25 meters per second, using a coolant. After grinding, the tools were lapped with a boron carbide paste, 200-250 grain size, on cast-iron lapping disks at a disk speed of 2 meters per second.

The mineral-ceramic cutting tools were tested in machining the inner chamfer of outer ball-bearing rings and boring the holes of bearing rings made of steel ShKh15. The rings were held in pneumatic collet chucks.

Preliminary machining of rings was done on multispindle automatic lathes and the face of the rings was ground on surface grinding machines.

In machining the inner chamfer of outer rings of bearings 305 on finishing machines, a cutting speed of 220-240 meters per minute and a feed of 0.1-0.2 millimeters per revolution (without coolant) were used. The life of mineral-ceramic tools was 1,000-1,200 rings when the entire length of the cutting edge was used, whereas the life of cutting tools with T5K10 hard-alloy tips under the same conditions is only 600-700 rings.

The tools produced a well-finished and mirrorlike surface.

With normal dulling, the ceramic tools did not need regrinding; only lapping with a cast-iron disk was necessary.

In operation, the cutting tools showed good results. There was no shearing action during the cutting process.

The use of tools with mechanically fastened mineral-ceramic tips is considered the most expedient because a saving in material for the tool shank can be effected, grinding of the tips is simplified, and the time required for changing a dull tool is shortened since only the ceramic tip needs to be changed.

In boring the outer rings of ball bearings type 204 and 203, machining was done on finishing lathes, without coolant, at a cutting speed of 150 meters per minute, feed of 0.4 millimeters per revolution, and depth of cut of 1.0-1.3 millimeters.

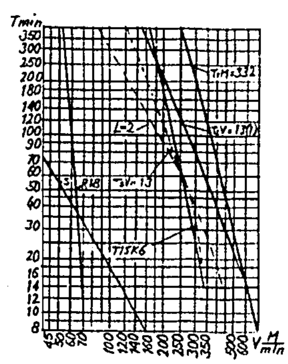
The life of cutting tools with mechanically fastened mineral-ceramic tips is 250-300 bearing rings.

The machined surface of the rings corresponds to the fifth class of finish according to GOST 2789-51.(4)

Effect of Cutting Conditions on Ceramic Tools

[for a discussion of the machining of cast iron with ceramic tools. The data which follows, taken from an article by the same authors, deals with the machining of steel.]

The graph below shows the life of cutting tools made of different tool materials in turning steel 45. These materials include R18 high-speed steel; T15K6 hard-alloy; and S, L-2, TsV-13(1), and TsM-332 ceramic materials.



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Tests have shown that a depth of cut up to 2.5 millimeters has comparatively little effect on the life of ceramic tools. Up to this limit, the depth of cut has considerably less effect on the life of the tools than the feed. When it exceeds 2.5 millimeters, the depth of cut begins to have more effect on the life of the tools than the feed. Therefore, the most suitable field of use of ceramic materials is in finish and semifinish machining.

When the ceramic cutting tools of various materials were tested at different feeds and depth of cut, it was found that in cutting a chip of large cross section, in turning steel 45, the tips will maintain a depth of cut up to 5 millimeters at a feed of 1.0 millimeters.

On the basis of experimental results, the following formulas were obtained for determining cutting speeds:

Material TsV-13

$$v_{90} = \frac{155}{s^{0.26}\, t^{0.03}}$$

Material TsM-332

$$v_{90} = \frac{203}{s^{0.37}\, t^{0.19}}$$

The surface finish obtained with ceramic tools is approximately the same as the finish obtained with T30K4 hard-alloy tools. The surface finished obtained with VK8 hard-alloy is considerably inferior.(5)

Methods of Fastening Ceramic Tools to Shanks

BF2 and BF4 adhesives for joining mineral-ceramic and hard-alloy tips to tool shanks were developed by the Scientific Research Institute of Plastics imeni Frunze. The BF4 has given better results than the BF2.

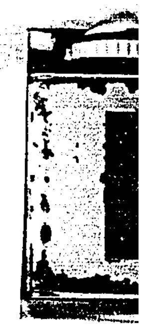
The BF adhesives have greater heat resistance than carbinol adhesive. They will maintain a strong joint up to 300 degrees, whereas carbinol adhesive will do so only up to 70 degrees.

The BF adhesives have a resin base and are soluble in ethyl alcohol.

When tips were fastened with BF adhesives, it was determined that the maximum amount of heat was concentrated at the fine surface layer of the cutting part of the tool and that the temperature at the heel did not exceed 300 degrees.(6)

The process of brazing mineral-ceramic cutting tips to tool shanks by preliminary heating of the tips and subsequent cooling of the brazed cutting tools in the furnace as it cools produces high-quality cutting tools. However, such a method is rather labor consuming.

In a new method of fastening the mineral-ceramic tip to the shank, suggested by V. I. Krotov, a cold tip is placed in the shank recess. When turning tools are brazed, a sheet of red copper is placed underneath the upper lip of the shank recess. When facing tools are brazed, small pieces of red copper 3-5 millimeters in diameter are placed in the open shank recess. The tip and the red copper are then sprinkled with dehydrated borax and the tool /with inserted tip/ is put in a cylindrical coil inductor (inner diameter of 80 millimeters for cutting tools from 16 x 25 to 20 x 30 millimeters in cross section) of a high-frequency-current unit.



For even and gradual heating, the tool is inserted in such a way that the head of the tool overhangs the inductor. The tool shank, therefore, and not the tip, is in the zone of magnetic flux. Heat is conducted through the shank metal to the brazing area. After the brazing area reaches a temperature of 800 degrees (bright cherry red), the tip of the tool is gradually brought into the zone of the magnetic flux, care being taken that the brazing area does not become heated unevenly, until the brazing area is at about the center of the inductor. The heating of the tool head and melting of the braze take place in 55-60 seconds; in other words, the temperature increases at the rate of 20 degrees per second.

After the tool is removed from the inductor, the tip is adjusted in the shank recess and the tool is placed under a hand press which, by pressing on the upper lip of the recess, exerts light pressure on the tip against the supporting surface of the shank recess. With facing tools, pressure is exerted simultaneously on /the lip above/ the open part of the recess to give the tip additional support. The tool is placed in an open box and cooled slowly.

The quality of cutting tools brazed by this method is adequate. Rupture of the tip has not been observed either after brazing and grinding or in operation. /Sketches of turning tool, facing tool, inductor, and hand press are in source, available in CIA./(7)

SOURCES

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